FABRICATION OF HgI_2 NUCLEAR RADIATION
DETECTORS BY MACHINE CLEAVING*

by

A. Levi, A. Burger, and M. Schieber
School of Applied Science and Technology
The Hebrew University of Jerusalem, Jerusalem, Israel

L. van den Berg
EG&G, Santa Barbara Operations
Goleta, California 93116

W.B. Yelon
University of Missouri Research Reactor and Department of Physics
University of Missouri-Columbia, Columbia, Missouri 65211

and

R.W. Alkire
Department of Chemistry
University of Missouri-Rolla, Rolla, Missouri 65401

ABSTRACT

DISCLAIMER
This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

A new device has been designed to facilitate the cleaving of thin sections from bulk crystals of mercuric iodide. Crystallographic perfection of the machine-cleaved sections was established by gamma-ray diffraction rocking curves and was found to be higher than the perfection of hand-cleaved sections or of as-grown thin platelets, approaching the perfection of string-sawn sections of HgI_2 . A correlation was found between the perfection and thickness of the machine-cleaved sections, i.e., the thicker the section the more perfect it is. Reproducibility of the fabrication was significantly improved by using machine cleaving in the fabrication process.

*This work was performed under the auspices of the U.S. Department of Energy under Contract No. DE-AC08-76NV01183. NOTE: By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive royalty-free license in and to any copyright covering this paper.

Reference to a company or product name does not imply approval or recommendation of the product by the U.S. Department of Energy to the exclusion of others that may be suitable.

MASTER

EAB

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

FABRICATION OF HgI_2 NUCLEAR RADIATION DETECTORS
BY MACHINE CLEAVING

by

A. Levi, A. Burger, and M. Schieber
School of Applied Science and Technology, The Hebrew University
of Jerusalem, Jerusalem, Israel

L. van den Berg
EG&G, Inc., Santa Barbara Operations, Goleta, CA 93116 USA

W.B. Yellon
University of Missouri Research Reactor and Department of Physics,
University of Missouri-Columbia, Columbia, Missouri 65211, USA

and

R.W. Alkire
Department of Chemistry,
University of Missouri-Rolla, Rolla, Missouri 65401

ABSTRACT

A new device has been designed to facilitate the cleaving of thin sections from bulk crystals of mercuric iodide. Crystallographic perfection of the machine-cleaved sections was established by gamma-ray diffraction rocking curves and was found to be higher than the perfection of hand-cleaved sections or of as-grown thin platelets, approaching the perfection of string-sawn sections of HgI_2 . A correlation was found between the perfection and thickness of the machine-cleaved

sections, i.e., the thicker the section the more perfect it is. Reproducibility of the fabrication was significantly improved by using machine cleaving in the fabrication process.

1. INTRODUCTION

Single crystals of HgI_2 weighing 20 to 200 g can be grown from the vapor phase using the TOM technique.^{1,2,3} In order to fabricate nuclear radiation detectors from these crystals, thin sections of about 0.4 to 0.8 mm thickness have to be prepared. Up until now, two methods have been used to obtain thin sections from the single crystals: 1) hand-cleaving using a razor blade, and 2) solution string sawing.

Recently, Yellon, et al⁴ have shown that hand cleaving causes severe damage to the crystallographic perfection of the material. Solution string sawing, usually followed by a chemical polishing process, causes the least damage to the crystal, but results in a significant loss of material from the original crystal volume when thin sections have to be prepared. It was therefore worthwhile to consider modified fabrication procedures, especially when loss of material is critical.

An alternative attempt to avoid mechanical damage was to grow platelets of adequate thickness, which could eventually eliminate both cleavage and sawing. Nuclear spectroscopic radiation detectors with very small contact areas of 3 to 6 mm² could be fabricated from these platelets and acceptable spectroscopic resolutions have been reported.^{5,6} However, the contact area of the platelets could not be increased because most of the area of the platelets usually had a lower perfection which could be observed even with the naked eye.

The present paper describes a new machine cleaver which preserves the perfection of detector sections, allows the fabrication of larger contact areas, and avoids loss of material as occurs with solution string sawing.

2. EXPERIMENTAL

A machine guillotine-type cleaver was built at the Hebrew University and is shown in Figure 1. The single crystal is installed on a micrometric stand. The angular orientation about the x- and y-axes of the stand can be adjusted within an accuracy of ± 3 seconds. The cleavage is then done by the smooth movement of the knife without the vibration caused by the human hand. The cleaved sections fabricated by machine cleaving had a very smooth, stepless, and highly reflective surface. Orientation of the crystal is now kept constant, and the sections are cut using only a translation movement perpendicular to the knife plane.

In order to compare the perfection of each of the four different kinds of preparation of thin sections of HgI_2 (hand-cleaving, machine-cleaving, solution wire sawing, and as-grown thin platelets), it was decided to use the gamma-diffraction, rocking-curves method. This method was recently developed for HgI_2 single crystal perfection characterization by W.B. Yellon et al.⁴ In addition, the nuclear spectroscopic resolution of detectors made by various methods of fabrication was measured.

3. RESULTS

The rocking curves of two machine-cleaved sections of different thicknesses and of one as-grown platelet are shown in Figure 2. The critical values which can be derived from these curves have been tabulated in Table 1, together with similar results from previous work. The nuclear spectroscopic performance of 10 machine-cleaved detectors fabricated from one crystal, 10 hand-cleaved detectors also fabricated from one crystal, and of 10 detectors fabricated from platelets grown in one run has been measured, and the results are given in Table 2.

4. DISCUSSION AND CONCLUSIONS

The data presented in the tables indicates some general trends which will be identified and discussed in the following paragraphs:

- a. The gamma radiation rocking curves of the machine-cleaved sections show that perfection of the machine-cleaved sections increases with increasing thickness of the section.
- b. Perfection of 0.6 mm and 0.8 mm machine-cleaved sections are comparable to the perfection of chemically sawn and polished sections which showed the best perfection in previous work.
- c. Perfection of the platelets is less than the perfection of machine-cleaved sections and is comparable to the perfection of hand-cleaved sections, although the nuclear spectroscopic resolution of the detectors fabricated on a very small area of the platelets is acceptable. The large full width at half maximum of the gamma-diffraction, rocking-curve peaks of the platelets can be explained by the fact that the largest part of the area of the platelets has a poor perfection, and only a very small part of the area has a good perfection. This is also supported by the shape of the rocking curves of the platelets, which consists of many peaks. Therefore, if one can recognize, by microscopic observation, the best transparent spot of the area and can apply a contact ($2-4 \text{ mm}^2$) on it, a good quality spectrometer for x-rays can be fabricated.⁷
- d. The average values of the FWHM's of the ^{241}Am peak for each group of 10 detectors are approximately the same. In this respect the mechanical cleaving method does not seem to offer a clear advantage. As a matter of fact, some of the manually-cleaved detectors are clearly superior to

the ones made from machine-cleaved sections. It is possible that crystal V-2-7 as grown had superior electronic properties than crystal H-1-53 and that by chance some hand-cleaved sections came out almost perfectly, so that occasionally good quality detectors could be fabricated. A similar effect can be observed for some detectors made from platelets where, on purpose, the best part was selected for contacting. To revolve this issue, more comparative experiments will have to be performed.

- e. The standard deviation of the FWHM's for machine-cleaved detectors, hand-cleaved detectors, and platelets shows that the machine-cleaved fabrication method gives a good reproducibility. This good reproducibility can be obtained because of the fine control ability of the machine-cleaving method. After a few initial cleavage trials, the (001) plane is found with great accuracy, and terraces or other defects could not be observed on the cleaved surfaces with an optical microscope. It is this superior reproducibility and the maximum use of the available crystal volume which may make machine cleaving a viable step in detector fabrication.

5. ACKNOWLEDGMENTS

Some of the authors (A. Levi, A. Burger and M. Schieber) wish to thank EG&G, Inc. Headquarters for a grant which covered part of the expenses of this research report.

REFERENCES

1. M. Schieber, W.F. Schnepple and L. van den Berg, J. Crystal Growth, 33 (1976) 145.
2. M. Schieber, I. Beinglass, A. Holzer, and G. Dishon, Nucl. Inst. Meth. 144 (1977) 469-476.

3. M. Schieber, I. Beinglass, G. Dishon, A. Holzer and G. Yaron, Nucl. Inst. Meth. 150 (1978) 71-77.
4. W.B. Yellon, R.W. Alkyre, M. Schieber, L. van den Berg, S. Rasmussen and G. Schneider, J. Appl. Phys. 52(7) (1981) 4604-4609.
5. P. Faile, A.J. Dabrowski, G.C. Huth and J.S. Iwanczyk, J. Crystal Growth 50 (1980) 752.
6. A. Burger, M. Roth and M. Schieber, J. Crystal Growth 56 (1982).
7. A.J. Dabrowski and G.C. Huth, IEEE Trans. Nucl. Sci. NS-25 (1978) 205.

Table 1. Gamma radiation rocking curves of sections prepared by four different methods of fabrication.

	Machine-cleaved V-1-50				Platelets P1 P2		Hand-Cleaved S-2-17†		Wire-Sawn† S-8-10 S-2-17	
Grade (†)	C				B		B		C	B
Thickness (mm)	0.20	0.40	0.60	0.80	0.2	0.6	~0.3	~0.6	0.65	0.535
FWHM (deg) Rocking curve	0.225	0.26	0.045	0.09	0.4	0.25	0.16	0.24	.02 -.04	0.1-.32
Full width at 10% max (deg) Rocking Curve	0.7	0.36	0.1	0.23	1.23	1.2	0.8	5.0	.035 -.09	0.4-1.5
No. of peaks	6	6	3	3	11	13	3	7	1-3	2-6

† Reprinted from Ref. 4.

Table 2. Spectroscopic resolution of detectors made by machine-cleaved (M-C), hand-cleaved (H-C) and as-grown platelets (P).

Det. No.	Spectral FWHM at 60 keV of ^{241}Am (keV)										Average (keV)	Standard Deviation (%)	Area (mm ²)	Thickness (mm)
	1	2	3	4	5	6	7	8	9	10				
(M-C) from H-1-53	4.2	4.2	3.6	4.0	3.9	4.3	3.8	4.1	3.9	4.0	4.0	5	20-25	0.5-0.6
(H-C) from V-2-7	2.5	2.8	3.0	2.7	4.2	4.5	3.1	3.7	4.6	5.3	3.6	25	20-25	0.5-0.6
(P) from Run 5	6.0	3.0	4.1	5.1	3.3	6.4	2.3	2.0	3.2	2.5	3.8	39	3-6	0.2-0.3

FIGURE CAPTIONS

Figure 1. (a) Photograph of a guillotine-type machine cleaver, and
(b) schematic diagram of the possible translations and rotations.

Figure 2. Rocking curves of the platelet P1 and two machine-cleaved sections
from V-1-50 having a thickness of 0.2 mm and 0.8 mm.

Figure 1a

Figure 1b

Figure 2

S-209-TP

FIG. 2